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Art. VIII.—*A Note on Solar Radiation in the Lyman Region and Far Ultra Violet.*

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(With Plate VII.)

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The D_1 and D_2 lines, according to Mitchell (1) reach a height of 1000 kms. in the Chromosphere, and Saha subsequently showed that the ionization potential of sodium (5·11 volts) is so low that above this level no appreciable quantity of sodium would remain un-ionized. The characteristic absorption lines of the ionized atom lie in the far ultra violet and the height which such atoms attain cannot therefore be directly ascertained. In following up this subject, Milne (2) suggested that since solar radiation in the far ultra violet is probably too weak to exert any appreciable pressure, the sodium atoms which chance to become ionized will not be supported, and he concluded that 1000 kms., the limit of the neutral atoms, would also be the limit of the ionized atoms. The Earth's atmosphere begins to absorb strongly beyond λ 3000, and we have as yet little or no knowledge of continuous absorption in the solar envelope. According to Fabry and Buisson (3), and also H. H. Plaskett (4), the continuous spectrum of the Sun conforms closely with that of a black body. How far we are at liberty to extend these results into the ultra violet is difficult to say. The intensity of solar radiation in the extreme ultra violet is therefore largely a matter of conjecture.

Observations made by the author[1] at the Eclipse in Sumatra, 1926, show that D_1 and D_2 reached 3300 kms. and it is suggested that stripped sodium atoms cannot exceed this level because the L radiations of sodium, the longest of which is 376·5 Å.U. (5), lie in the Lyman region, where the intensity of solar radiation is insufficient to support such atoms. It remains to show some jus-

1.—A full account of this work will be published in due course. The observations were made with a moving plate objective grating spectrograph. On the spectrogram reproduced the scale of heights is such that 1 mm. on the spectrogram is equivalent to 275 kms. in the chromosphere. Direct measures give Na 3300 kms., Ca 1500 kms., Ca 10,000 kms., Ba 1400 kms. These results are in good agreement with observations (unpublished), made in Australia at the Total Solar Eclipse, 1922. Corrections have still to be made for atmospheric and instrumental absorptions or losses, also spectral sensitivity of the plate emulsion. The combined effect of these, however, does not vary much over the range of the spectrum under consideration, so the relative heights as measured directly from the spectrogram will not be seriously in error. On the original spectrogram the precaution has been taken to impress a standard solar spectrum and standard squares, so that the above corrections may be ascertained.

tification for this suggestion, and also the assumption made by Milne regarding the intensity of solar radiation in the far ultra violet.

When the valency electron of the sodium atom is removed we are left with a "stripped atom," and there are then two possible alternatives:—

(*a*) The next absorption may be one of the L radiations, or

(*b*) One of the L electrons may be only lifted into one of the M levels, leaving the atom in the normal state for the absorption of the principal series of enhanced lines[2]. In such a state the atom is not likely to capture an electron—in fact, it is more easily ionized than before.

If any sodium atoms exist above 3300 kms., there is little doubt that they must be in an almost completely ionized state. Ionized calcium exists to 10,000 kms., and we will therefore have a mixture of stripped sodium, ionized calcium and free electrons. The ionization potential of calcium, 6·08 volts, is considerably higher than that of sodium, 5·11 volts, so there will be a tendency for the ionized calcium atoms to capture electrons and become neutral. In that case, we would expect to find some trace of λ 4227 neutral calcium above 3300 kms. In reality my observations show that λ 4227 only reaches 1500 kms. The inference to be drawn is that the existence of stripped, and hence ionized, sodium atoms above 1500 kms. is extremely unlikely, and as a corollary that solar radiation, in the extreme ultra violet and Lyman region, is very weak.

Before dismissing this subject, it might be mentioned that the ionization potential of barium, 5·12 volts (6), is almost identical with that of sodium, but in this case the principal lines of the ionized atom lie in the easily accessible region of the solar spectrum. A comparison of the heights of the ionized lines λ 4934 and λ 4554 of barium, and λ 4227 neutral calcium will, therefore, afford an admirable test (other things being equal) of the foregoing theory.

λ 4934 and λ 4554 not only lie in the observable region, but near F and between F and G respectively, in which region we know solar radiation can exert a very strong pressure. We might therefore expect λ 4934 and λ 4554 to reach heights commensurate with the H and K lines, which lines reach 10,000 kms. In reality λ 4934 only reaches 1400 kms., which is in keeping with the theory advanced. λ 4554, unfortunately, cannot be used to test the theory as this line appears as a blend with a line of zirconium.

2.—A sodium atom which has lost its valency electron is referred to as a stripped atom. In such a state the atom is capable of absorbing and subsequently emitting a series of radiations in the Lyman region, the longest of which is 376·5 A U. The term "ionized sodium atom" is used to denote a sodium atom with its valency electron removed to infinity as before, but with one of its L electrons raised to one of the M levels. In this state the atom is capable of absorbing, and subsequently emitting the well-known, many-lined, enhanced spectrum.

Bearing on Terrestrial Phenomena.

The electrical state of the Earth's upper atmosphere is of considerable importance in connection with the transmission of wireless waves, and was the subject of a recent discussion of the Royal Society (7). The evidence obtained from Radio work indicates that the upper air is considerably ionized or may contain a moderate number of free electrons. Appleton and Barnett (8) have assigned 10^5 as the lower limit to the number of free electrons per cubic cm. at 80 kms. above the Earth's surface, but there is ample evidence to show that the concentration is considerably greater. The electrical state of the upper air has been ascribed to various causes, but mainly to direct ionization by ultra violet light in the Sun's rays, and also to the formation of ozone by wave lengths shorter than 1800 Å.U.(7) and its subsequent decomposition into ions. The pertinent question is whether sunlight contains the ultra violet radiations necessary for either (or both) of these processes.

In discussing this subject it seems desirable to distinguish between two kinds of radiation, bright line emission and continuous emission. The latter we have already seen to be weak in the far ultra violet and Lyman region, and need not be considered any further at present.

According to Russell (6), the percentage of calcium remaining un-ionized in the Sun's reversing layer at a height where the pressure falls to 10^{-6} Ats. is 0·007 and of ionized calcium 83·6. These figures if correct show that even at moderate elevations an appreciable quantity of calcium (approximately 16·4%) is doubly ionized, and it has been suggested to me by Professor Grant that if the high level calcium atoms eventually become doubly ionized there would be a copious emission of just those short wave lengths requisite for ionization of the Earth's upper atmosphere.

We have already seen that the reason why the ionized and stripped sodium atoms are not supported is because of the Sun's poverty in continuous radiation in the far ultra violet and the Lyman region. These are also the radiations necessary to support the doubly ionized calcium atoms, so we are faced with the conclusion that if the calcium atoms become doubly ionized they will not be supported, and will fall inwards towards the Sun until they capture an electron with which to absorb. The intensity of the short wave length radiations from this source will depend on how quickly the doubly ionized atom can find an electron, and climb up into the high levels again. St. John (9) gives the velocity of ascent of ionized calcium as 2 kms. sec. $^{-1}$. If a mobile equilibrium is established, it is plain that the intensity of the doubly ionized radiations will not be very strong. On the other hand, in spite of the low pressure at great heights, Milne (10) has given good reasons for believing that there will scarcely be an appreciable amount of the second stage ionization.

When all these matters are taken into account it seems that the theory of the formation of ozone at great elevations and the hypothesis of photo-electric ionization of the upper atmosphere by ultra violet radiations between say λ 3000 and the region of long X-rays are rather unsatisfactory. Nevertheless, the small intensity of these radiations in the Sun's rays may suffice and the ionization products may accumulate with time, but the hypotheses of very penetrating radiation (11) and swift-moving charged particles (12) seem on the whole preferable.

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8. *Ibid.*, cix., p. 621, 1925.
9. *Astrophys. Journ.*, xxxii., p. 36, 1910.
10. *Monthly Notices, R.A.S.*, lxxxiv., p. 354.
11. *Preus. Akad. Wiss. Berlin*, xxxiv., pp. 366-377.
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EXPLANATION OF PLATE VII.

Flash Spectrum. Total Solar Eclipse, Sumatra, January 14th, 1926.